Visuospatial Ability As A Predictor Of Novice Performance In Ultrasound – Guided Regional Anesthesia

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ABSTRACT:

Background: Visuospatial ability correlates positively with novice performance of simple laparoscopic tasks. The aims of this study were to identify if visuospatial ability could predict technical performance of an ultrasound–guided needle task by novice operators, and to describe how emotional state, intelligence and fear of failure impact on this.

Methods: Sixty medical student volunteers enrolled in this observational study. We used an instructional video to standardize training for ultrasound-guided needle advancement in a turkey breast model and assessed volunteers' performance independently by two assessors using composite error score (CES) and global rating scale (GRS). We assessed their 'visuospatial ability' with mental rotation test (MRT), group embedded figures test (GEFT) and Alice Heim group ability (AH4) test. 'Emotional state' was judged with UWIST mood adjective checklist (UMACL) and fear of failure, and 'general cognitive ability' with numerical reasoning test (NRT-20).

Results: High CES scores (high error rate) were associated with low MRT scores ($\rho = -0.54$; $P<0.001$). Better GRS scores were associated with better MRT scores ($\rho = 0.47$; $P<0.001$). Regarding emotions, GRS scores were low when anxiety levels were high ($\rho = -0.35$; $P = 0.005$) and CES scores (errors) were low when individuals reported feeling vigorous and active ($\rho = -0.30$; $P = 0.01$).

Conclusions: MRT predicts novice performance of an ultrasound-guided needling task on a turkey model, and as a trait measure could be used as a tool to focus training resources on less able individuals. Anxiety adversely affects performance. Both may therefore prove useful in directing targeted training in USGRA.

INTRODUCTION:

The ability to perform practical procedures competently is essential to the safe practice of anesthesia. Ultrasound–guided regional anesthesia (USGRA) is a complex, invasive procedural skill that requires manual dexterity, hand-eye coordination and a working knowledge of sono-anatomy.[1] International regional anesthesia societies have emphasized the need for training and competency assessment in USGRA to ensure safe practice.[2-4] However, some trainees will learn more quickly than others.[5] Early identification of those who may require additional support is key to developing efficient expertise acquisition within the time constraints of postgraduate training.

Mental rotation is a visuospatial ability to mentally rotate and manipulate 2-D and 3-D objects. Mental rotation correlates positively with novice performance of simple laparoscopic tasks on bench-top models.[6-9] At a basic level, it is possible that laparoscopy and USGRA are similar with respect to the interaction of the operator's hands and eyes with the ultrasound probe/laparoscope, the patient and the screen. The importance of visuospatial ability has been emphasized in USGRA skills acquisition.[1] However, there is little evidence to support the use of visuospatial testing to identify individuals who may benefit from early, targeted training in USGRA. The primary aim of this study was to determine whether visuospatial ability could predict technical performance of an ultrasound-guided needle task by novice operators. Specifically, we chose to study the Mental Rotation Test (MRT), the Group Embedded Figures Test (GEFT), and the Alice Heim Group Ability Test (AH4).

Previous studies have considered the impact of visuospatial ability on novice skill performance in isolation. However, the role of traits and state emotional processes are also important for a fuller understanding of healthcare provision through their influence on clinical skills acquisition.[10,11] Specifically, previous studies have not investigated the interplay between skill performance and emotional processing.[1,12-14] Two emotional components are relevant here. State anxiety is well known to be related to performance.[15] The trait, fear of failure, is a sub-clinical form of state anxiety when success is being valued.[16,17] Fear of failure could potentially hinder performance.[18,19] In addition, general cognitive ability is considered to be one of the best predictors of performance overall.[20] Therefore, we also aimed to study the relationship between emotional state, fear of failure and intelligence with novice skill performance of an ultrasound-guided needle task.

MATERIALS AND METHODS:

The study was reviewed and approved by the University of Nottingham Medical School Research Ethics Committee (Approval Reference; L13092012 SCS Anesthesia). Medical students from the University of Nottingham Medical School were invited to participate in the study through poster advertising. Students who expressed a wish to participate were emailed a participant information leaflet and an invitation to attend the study. Written informed consent for the study, including video recording, was taken from all participants.

Design: This single center, prospective, blinded observational study was conducted at the University Department of Anesthesia, Queen's Medical Centre, Nottingham University Hospitals NHS Trust, Nottingham UK.

Subjects with previous experience of ultrasound scanning or of performing regional anesthesia were excluded from the study. The study was organized in four phases [figure 1]. The enrolled medical students were asked to undergo and complete all four phases of the study. Participants' identities were masked throughout the study, and their assessments were concealed from view within individual folders. Assessors of the ultrasound-guided needling task (phase four) were blinded to the outcomes of the preceding assessments.

PHASE ONE:

We collected basic demographic data including age, sex, year of study in medical school and previous experience of USGRA.

PHASE TWO:

This phase consisted of standardized visuospatial, emotional, and numerical reasoning assessments of the study participants. The assessments were paper-based and administered under examination conditions, as per their standardization. Participants were blinded to the study hypothesis and their test scores. Brief descriptions of each visuospatial, emotional, and numerical reasoning assessment are described in the next paragraphs.

Visuospatial Assessments:

The visuospatial assessments consisted of the Mental Rotation Test (MRT), Group Embedded Figures Test (GEFT) and Alice Heim Group Ability Test (AH4).

Mental rotation Test (MRT)[21-23]

There are four different variations of MRT, which include MRT–A, MRT–B, MRT–C and MRT–D respectively. We used MRT–A, which consists of 24 problem figures. Each problem task has a target figure on the left and four stimulus figures on the right. Two of these stimulus figures are rotated versions of the target figure and two of the stimulus figures cannot be matched to the target figure. The aim is to mentally rotate the figures around the vertical axis to find the two correct rotated versions of the target figure. Participants were given four minutes to complete the first set of 12 problem tasks, followed by a one-minute break before completing the second set of 12 problem tasks in the next four minutes.

The Group Embedded Figures Test (GEFT)[24,25]

The GEFT measures field-independence, which is the ability to perform a focal task independently of any background information or distracters. The aim is to find a previously seen simple figure within a larger complex figure, which has been structured in a way to obscure or embed the simple figure. The participants were required to identify and outline accurately a simple shape embedded in a complex figure. The test consists of three sections. The participants were initially given two minutes to complete the seven problems in the first section. Following this, second and third sections consisting of nine problems each respectively were completed in 10 minutes.

Alice Heim Group Ability Test (AH4)[26]

The AH4 is designed as a group test of general intelligence, which primarily assesses deductive reasoning including verbal, mathematical and spatial reasoning. We used AH4 to assess spatial reasoning skills, which is the ability to visualize, mentally rotate and manipulate two-dimensional or three-dimensional shapes or patterns. The test consists of 65 questions and participants were given 10 minutes to complete as many questions as possible.

Emotional Assessments:

Emotional processes that tap into state anxiety or tense arousal, as well as positive mood states (e.g., energetic arousal), were assessed using the UWIST Mood Adjective Checklist (UMACL) and Fear of Failure.

UWIST Mood Adjective Checklist (UMACL)[27]

The UMACL is used to measure mood and comprises three bipolar scales: energetic arousal (EA) [vigorous vs. tired: coefficient alpha = .79], tense arousal (TA) [nervous vs. relaxed: coefficient alpha = .76] and hedonic tone (HT) [pleasant vs. unpleasant mood: coefficient alpha = .81].[28] In addition to these scales, a mono-polar anger/frustration (AF: coefficient alpha = .80) scale was also used. The participants were instructed to complete the UMACL checklist according to their present mood using 28 adjectives each on a four – point scale (‘definitely’, ‘slightly’, ‘slightly not’ or ‘definitely not’).

Fear of Failure[29]

‘Fear of failure’ assesses the general preference to be motivated not to succeed but to avoid failing. This assessment consists of four statements pertaining to fear of failure, each scored on a four – point scale (‘always’, ‘often’, ‘rarely’ and ‘never’). Scores were then obtained by summating the item scores. The reported coefficient alpha was .70.

Numerical Reasoning Assessments:

Numerical Reasoning Test (NRT-20)[*]

This test measures mathematical and logical reasoning via 20 short reasoning problems based on numbers that do not require any previous training in mathematics. It is a test of fluid intelligence, which depicts skills of problem solving, abstract reasoning, and ability to learn new things, irrespective of prior knowledge or education. There are 20 items,

[*] Chamorro-Premuzic T: The Numerical Reasoning Test 20-Items (NRT-20). Goldsmiths: University of London, 2008. (Unpublished Test)

which include series completion (numbers and matrices), basic arithmetic problems (computational speed), and other deductive reasoning tasks. The participants were given 15 minutes to solve as many problems as possible.

PHASE THREE:

In this phase the participants were given 30 minutes to watch and review an 11 – minute video[30] mapped to specific learning objectives, which modeled expert performance of ultrasound-guided needle advancement in a turkey breast model.

The learning objectives were:

I. Switch on the ultrasound machine (S-Series, Sonosite Limited, Hitchen, UK).

II. Correctly orientate the ultrasound probe (linear, 38mm) in relation to the display on the screen.

III. Ensure adequate application of conducting gel to enhance ultrasound transmission and picture quality.

IV. Locate and identify the target (olive) within the turkey breast.

V. Adjust the gain function to improve the quality of the image by altering brightness of the picture.

VI. Alter the depth of the image to obtain a suitable image of the target.

VII. Using an in-plane approach, insert a 50 mm Stimuplex® A needle (B. Braun, Melsungen, Germany) into the turkey breast and aim to place the needle tip at the 12 o'clock position, as indicated by the attending assessors, above the upper edge of the target, without piercing the target.

PHASE FOUR:

The fourth phase included an ultrasound-guided needling task and its assessment. Participants were asked to complete the ultrasound-guided needling task, as demonstrated in the video, on a turkey breast model[31,32] using a standard ultrasound transducer probe (38-mm high-frequency linear array transducer; HFL38X 13-6 MHz, Sonosite Limited, Hitchen, UK). In order to improve realism, the turkey breast model was inserted into the draped groin recess of a Laerdal® IV Torso manikin (Laerdal Medical Limited, Orpington, Kent, UK), which was used solely for this study. The participants received no help or feedback before or during the task. Study participation ceased once the ultrasound-guided needling task was completed.

Participants were independently assessed by two anesthesiologists experienced in USGRA as they performed the task. The assessors used two previously validated assessments of USGRA technical performance; composite error score (CES)[32-34] [appendix 1] and global rating scale (GRS)[35-37] [appendix 2]. The assessors had undergone specific training and practice in the use of these assessment tools. The CES was calculated by adding the total number of errors, number of needle passes and image quality score for each participant. A lower composite error score is associated with better accuracy and task performance. The GRS consisted of seven items each rated on a five – point scale. The GRS predominantly assessed more general behaviors and the overall performance of the participant.

Statistical Analysis:

Descriptive statistics for demographic and outcome measure data were calculated. CES data follow a non-normal distribution, and are thus presented as median (IQR). Normality of other data was assessed by histogram and the Shapiro-Wilk and Skewness / Kurtosis tests.

We performed an initial exploratory analysis using Spearman's correlation coefficient 'ρ' (rho) to determine which of the six explanatory variables was the most predictive of better task performance. The count data (CES) were over-dispersed. This was unlikely due to excessive zeros as the proportion of extra zeros was considerably small (4/60 = 6.66 %); therefore negative-binomial regression analysis was conducted for CES. For continuous data the relationship between each potential explanatory variable and GRS was evaluated in an ordinary least square (OLS) regression. Bonferroni corrections were applied for multiple testing. We then created a regression model using the explanatory variable most predictive of performance. In order to examine which aspects of USGRA technical performance were most strongly correlated with visuospatial ability, we then deconstructed both assessments into their respective domains in order to perform a sub-analysis with the predictive variable; this sub-analysis was outside the previous validation of the CES and GRS. To achieve a study power of 0.8 ($\alpha = 0.05$), we calculated that we would need to recruit 60 participants for this model with an assumed moderate effect size[38] ($r = 0.3 – 0.5$).

We chose to make non-pairwise comparisons between males and females in order to determine whether any differences in visuospatial ability existed. In all cases, we used P – values less than 0.05 (two-tailed) to indicate statistical significance.

Reliability of the assessment tools i.e. CES and GRS, was evaluated using Intra-class correlation coefficient (ICC), Cronbach's alpha coefficient and standard error of the measurement as a percentage of the mean (SEM [%]).[39,40] The statistical analysis software STATA/IC version 10.0 (StataCorp, Texas, USA) was used for data analysis.

RESULTS:

All individuals who expressed an interest in participating in the study were recruited. Participant demographics and summary statistics for visuospatial ability and task performance are summarized in table 1. Males were found to exhibit better mental rotation skills compared to females ($P < 0.001$) [table 2].

Reliability of CES and GRS:

The intra-class correlation coefficient and SEM (%) for CES and GRS was 0.97 (15.29 %) and 0.91 (8.53 %) respectively; this demonstrates a high degree of inter-rater agreement. Similarly, Cronbach's alpha coefficient and SEM (%) for CES and GRS was 0.98 (9.49 %) and 0.96 (5.69 %) respectively; this demonstrates a high degree of inter-item consistency.

Composite error score (CES) versus Visuospatial ability assessments:

Of the three visuospatial assessments (MRT, GEFT, AH4), only MRT correlated significantly with CES ($\rho = -0.54$; $P < 0.001$) [figure 2, table 3], indicating that a high error rate is associated with low MRT scores. The negative binomial regression coefficients for each variable showed that for each unit increase in MRT, the expected log count of the CES decreases by 0.08-unit ($P < 0.001$).

After Bonferroni adjustments ($P < 0.0016$), only '*needle advancement without visualization of needle tip*' ($\rho = -0.52$; $P < 0.001$) and '*number of needle passes*' ($\rho = -0.45$; $P < 0.001$) correlated significantly with MRT.

Global rating scale (GRS) versus Visuospatial ability assessments:

Of the three visuospatial assessments (MRT, GEFT, AH4), only MRT correlated significantly with GRS ($\rho = 0.47$; $P < 0.001$) [figure 3, table 3], indicating that better performance was associated with better mental rotation skills. An ordinary least square regression established the univariate association of GRS with MRT showing that for a one-unit increase in MRT we would expect a 0.43-unit increase in GRS ($P = 0.002$).

After Bonferroni adjustments ($P < 0.0031$), only '*time and motion*' ($\rho = 0.44$; $P < 0.001$), '*instrument handling*' ($\rho = 0.47$; $P < 0.001$) and '*flow of procedure*' ($\rho = 0.44$; $P < 0.001$) correlated significantly with MRT.

Composite error score (CES) versus Emotional assessments:

Of the UMACL, energetic arousal (EA) was found to correlate negatively with CES ($\rho = -0.30$; $P = 0.01$) [table 3]. By contrast, tense arousal (TA) correlated positively but weakly with CES ($\rho = 0.26$; $P = 0.04$) [table 3]. This showed that errors would be low in vigorous, active individuals and high in anxious individuals.

The negative binomial regression coefficients for each of the variable showed that for each unit increase on EA, the expected log count of the CES decreases by 0.07-unit ($P = 0.02$).

Global rating scale (GRS) versus Emotional assessments:

Of the UMACL, only tense arousal (TA) correlated negatively with GRS ($\rho = -0.35$; $P = 0.005$) [table 3]. This showed that GRS quality scores would be low when anxiety level is high.

An ordinary least square regression established the univariate association of GRS with TA showing that for a one-unit increase in TA we would expect a 0.54-unit decrease in GRS ($P = 0.01$).

DISCUSSION:

The results indicate that MRT predicts technical performance of an ultrasound-guided needle advancement task by novice operators. The study shows that males are likely to have better mental rotation capabilities than females. This is in line with two previous meta-analyses[41,23] which showed effect sizes around 0.95 favoring males. This difference means that the MRT cannot be used as a selection tool for medical posts, i.e. high stakes assessment, as men are likely to be preferentially selected and this would introduce indirect sexual discrimination against women. However, that is not to say that males with better MRT scores perform better at the task. Two previous studies of laparoscopic skills have demonstrated that gender does not affect psychomotor performance[42,43], though the affect of MRT scores of both males and females remained unknown. In an observational study of surgical trainees with very limited laparoscopic experience, Grantcharov[43] demonstrated that male trainee surgeons made a similar number of errors and unnecessary hand movements as females during their performance of six simulated laparoscopic tasks.

One may suggest that it would be useful to provide a range of MRT scores wherein learners could benefit the most from focused training. However, we are unable to do so at this stage of our work. While our study shows that MRT has a predictive validity for performance of an ultrasound-guided needle task, it does not indicate at what point MRT performance can be defined as adequate or not. Despite this limitation, we believe that it is reasonable to state that low error rates, better image quality, and better global performance are associated with higher MRT scores. Therefore, strategies that aim to develop mental rotation skills could be developed and used to improve ultrasound-guided needle advancement skills.

We also found that negative mood adversely affects performance. Good performance, therefore, appears to be a function of visuospatial ability and reducing anxiety. Thus, a second practical implication of our study is that stress and anxiety when performing the task may need to be reduced in the training and learning environment. However, in the real clinical setting some level of anxiety will be associated with any clinical intervention, and thus the degree of stress elicited by the task may itself increase its validity.[10] It may be more relevant for educators to develop curricula that allow novice practitioners to learn the necessary coping skills to deal with the emotional costs of this type of work and procedure.

Limitations are integral to any investigation and warrant specific comment here. Aside from the ethical problems of allowing novice practitioners to practice on real patients, it is likely that anatomical differences, doctor-patient interactions and the pressures of achieving successful blocks would generate inconsistent results in real clinical situations.[1,33] For the purpose of this study, we used a turkey-breast bench model rather than *in-vivo* needling. Despite the lack of clinical context, we believe that our participants experienced an "examination-like" stress caused by their assessments during the study. In addition, "live assessment" of the participants may have added to their stress levels. It is likely that the combined stress and fear could produce detrimental and variable effects on performance such as that in clinical practice.[15,44,45] Despite the limitations of the turkey-breast bench model, it is accepted as an initial means to evaluate novice performance in USGRA[3] and to perform training in this complex technical task.[31] As such, we felt that our bench-top simulation provided a reproducible and realistic environment in which to assess our subjects.

The subjects were medical students and not practicing doctors, therefore one could argue that with seniority and experience there is an inherent level of psychomotor expertise, which confers an improved ability to perform new psychomotor skills. Thus, it could be debated that had we studied anesthesiology residents, the correlations between MRT and GRS or CES may have been weaker. However, previous work has demonstrated that medical student performance of an ultrasound-guided needle task is broadly comparable to that of novice resident doctors.[32,33] Hence, we do not consider that the use of medical student volunteers presents a significant limitation to our study; rather the fact that they have no experience may be considered a positive aspect of the study.

We have used assessments of visuospatial ability, emotional processing and general cognitive ability, which are considered to be valid and reliable.[21-27] With regard to CES and GRS, we have demonstrated high levels of inter-rater agreement and internal consistency of the assessment tools; this is in line with the previous findings.[33,37] We believe that the high inter-rater agreement reflects the assessor training with the CES and GRS tools, prior to recruitment. As such, we believe that our measurement of task performance is both reliable and valid.

Lastly, we have attempted to mitigate for any bias in assessment by asking our assessors to rate the participants' performance independent of one another, and without knowledge of the participants' scores in the various psychological assessments completed beforehand.

The premise of this study was to identify whether visuospatial ability could be used to predict technical performance of an ultrasound-guided needle task by novice operators. In doing so, we have identified correlations between performance, mental rotation skills, and negative mood. As a trait measure, MRT has the potential to be used as a tool to focus educational and training resources on individuals who have less ability to perform ultrasound-guided needle tasks.

Future research could investigate whether specific training interventions could transform visuospatial ability and thus enhance skills acquisition in USGRA. In broader terms, we believe that the predictive value of MRT in video-laryngoscopy and fibreoptic intubation should be investigated. With regard to MRT as a screening tool to focus training, we believe that future studies need to assess the sensitivity and specificity of MRT in this context.

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Table 1. Participant Demographics and Summary Statistics for Visuospatial Ability and Task Performance

Participant Demographics	
Characteristics	**Overall N=60**
Age in years, Mean (SD)	23.3 (4.3)
Gender	
Male (n, %)	30 (50)
Female (n, %)	30 (50)
*** Year of study in medical school**	
Year 1 (n, %)	08 (14.0)
Year 2 (n, %)	21 (36.8)
Year 3 (n, %)	13 (22.8)
Year 4 (n, %)	11 (19.3)
Year 5 (n, %)	04 (7.0)

Summary Statistics	
† Assessment	**Score**
MRT (mean, SD)	13.9 (5.3)
GEFT (median, IQR)	17.0 (14.0 – 17.5)
AH4 (median, IQR)	60.0 (53.0 – 63.0)
[UMACL] EA (median, IQR)	19.0 (16.5 – 21.5)
[UMACL] TA (mean, SD)	15.2 (3.4)
[UMACL] HT (median, IQR)	27.0 (25.0 – 29.0)
[UMACL] AF (median, IQR)	6.0 (5.0 – 9.0)
Fear of failure (mean, SD)	6.8 (1.6)
NRT-20 (mean, SD)	13.9 (2.5)
CES (median, IQR)	6.0 (3.0 – 10.0)
GRS (mean, SD)	19.7 (6.0)

***** 3 (5%) missing
† Mean and SD (standard deviation) used for continuous variables with a normal distribution and median and IQR (Interquartile range) for continuous variables not normally distributed.
MRT – Mental Rotation Test; GEFT – The Group Embedded Figures Test; AH4 – Alice Heim Group Ability Test; [UMACL] – UWIST Mood Adjective Checklist; EA – Energetic Arousal; TA – Tense Arousal; HT – Hedonic Tone; AF – Anger/Frustration; NRT-20 – Numerical Reasoning Test; CES – Composite Error Score; GRS – Global Rating Scale.

Table 2. MRT Scores according to the Sex of the Participants

Gender	Number (%)	MRT (Mean)	SD	95 % CI	P – Value
Female	30 (50)	10.9	4.64	9.16 – 12.63	< 0.001
Male	30 (50)	17.0	4.15	15.44 – 18.55	

Values are Mean and SD – Standard deviation; CI – Confidence Interval; MRT – Mental Rotation Test.

Table 3 Correlation of CES & GRS with Visuospatial, Emotional and Numerical Reasoning Assessments

Visuospatial, Emotional & Numerical Reasoning Assessments	**Spearman's correlation coefficient (ρ)**	
	CES	**GRS**
MRT	−0.54 (P < 0.001)	0.47 (P < 0.001)
AH4	−0.09 (P = 0.49)	0.09 (P = 0.49)
GEFT	−0.06 (P = 0.60)	0.00 (P = 0.95)
UMACL		
• *Energetic Arousal (EA)*	−0.30 (P = 0.01)	0.06 (P = 0.62)
• *Tense Arousal (TA)*	0.26 (P = 0.04)	−0.35 (P = 0.005)
• *Hedonic Tone (HT)*	−0.22 (P = 0.08)	0.18 (P = 0.15)
• *Anger/Frustration (AF)*	0.16 (P = 0.21)	−0.19 (P = 0.13)
Fear of Failure	0.05 (P = 0.69)	−0.07 (P = 0.57)
NRT-20	0.01 (P = 0.93)	−0.05 (P = 0.69)

Spearman's correlation coefficient (ρ) of Composite Error Score (CES) and Global Rating Scale (GRS) with visuospatial, emotional and numerical reasoning assessments; Significance at $P < 0.05$.
MRT – Mental Rotation Test; AH4 – Alice Heim Group Ability Test; GEFT – The Group Embedded Figures Test; [UMACL] – UWIST Mood Adjective Checklist; NRT-20 – Numerical Reasoning Test.

Appendix 1

Visuo-spatial ability as a predictor of novice performance in ultrasound-guided regional anaesthesia (UGRA).

Participant number ☐ **Study period** ☐

Errors - Please tick each time an error is made

Needle advanced without visualisation of needle tip	
Failure to identify the target	
Failure to recognise orientation of probe with the image screen	
Unintentional probe movement	
Target malpositioned on screen, including incorrect depth selection	
Attention focussed on hand and not image as needle advanced	

Total number of errors ☐ **Box A**

Number of needle passes* ☐ **Box B**

** A needle pass is defined as a new puncture of the turkey breast or if the needle is withdrawn towards the exterior of the turkey breast.*

Image quality scale (select one)

Scale	Image quality	Description
0	Ideal	· Olive viewed on highest resolution & all contents visualized · Whole needle seen as contacted wall
1	Good	· Olive imaged well enough to define all aspects of contents · Needle tip & part of shaft seen as contacted wall
2	Satisfactory	· Olive visualized so at least wall was identifiable · Needle tip seen as contacted wall
3	Poor	· Olive wall was only partly visualized · Needle contact was identifiable only by tissue distortion

0	**Ideal**
1	**Good**
2	**Satisfactory**
3	**Poor**

☐ **Box C**

Composite Error Score
(Box A + Box B + Box C) ☐

Time to perform task ☐ s

Appendix 2

Visuo-spatial ability as a predictor of novice performance in ultrasound-guided regional anaesthesia (UGRA).

Participant Number [ ] **Study Period** [ ]

Global Rating Scale for UGRA.

Please tick and score each of the 7 items below appropriately;

	1	2	3	4	5
Preparation for procedure	Did not organise equipment well Has to stop procedure frequently to prepare equipment. [ ]	[ ]	Equipment generally organised. Occasionally has to stop and prepare items. [ ]	[ ]	All equipment neatly organised, prepared and ready for use. [ ]
Time and motion	Many unnecessary moves. [ ]	[ ]	Efficient time/motion but some unnecessary moves. [ ]	[ ]	Clear economy of movement and maximum efficiency. [ ]
Instrument handling	Repeatedly makes tentative or awkward moves with instruments. [ ]	[ ]	Competent use of instruments but occasionally appeared stiff or awkward. [ ]	[ ]	Fluid moves with instruments and no awkwardness. [ ]
Flow of Procedure	Frequently stopped procedure and seemed unsure of next move. [ ]	[ ]	Demonstrated some forward planning with reasonable progression of procedure. [ ]	[ ]	Obviously planned course of procedure with effortless flow from one move to the next. [ ]
Image quality	Inadequate image. Target partially visualised. Needle movement only identifiable by tissue distortion. [ ]	[ ]	Good image. Most of target visualised. Needle tip and part of needle shaft visible. [ ]	[ ]	Outstanding image. Unequivocal image with complete structure visualised. Whole of needle visible. [ ]
Knowledge of procedure	Deficient knowledge. [ ]	[ ]	Knew all important steps of procedure [ ]	[ ]	Demonstrated familarity with all aspects of procedure [ ]
Overall performance	Very poor. [ ]	[ ]	Competent. [ ]	[ ]	Clearly superior. [ ]

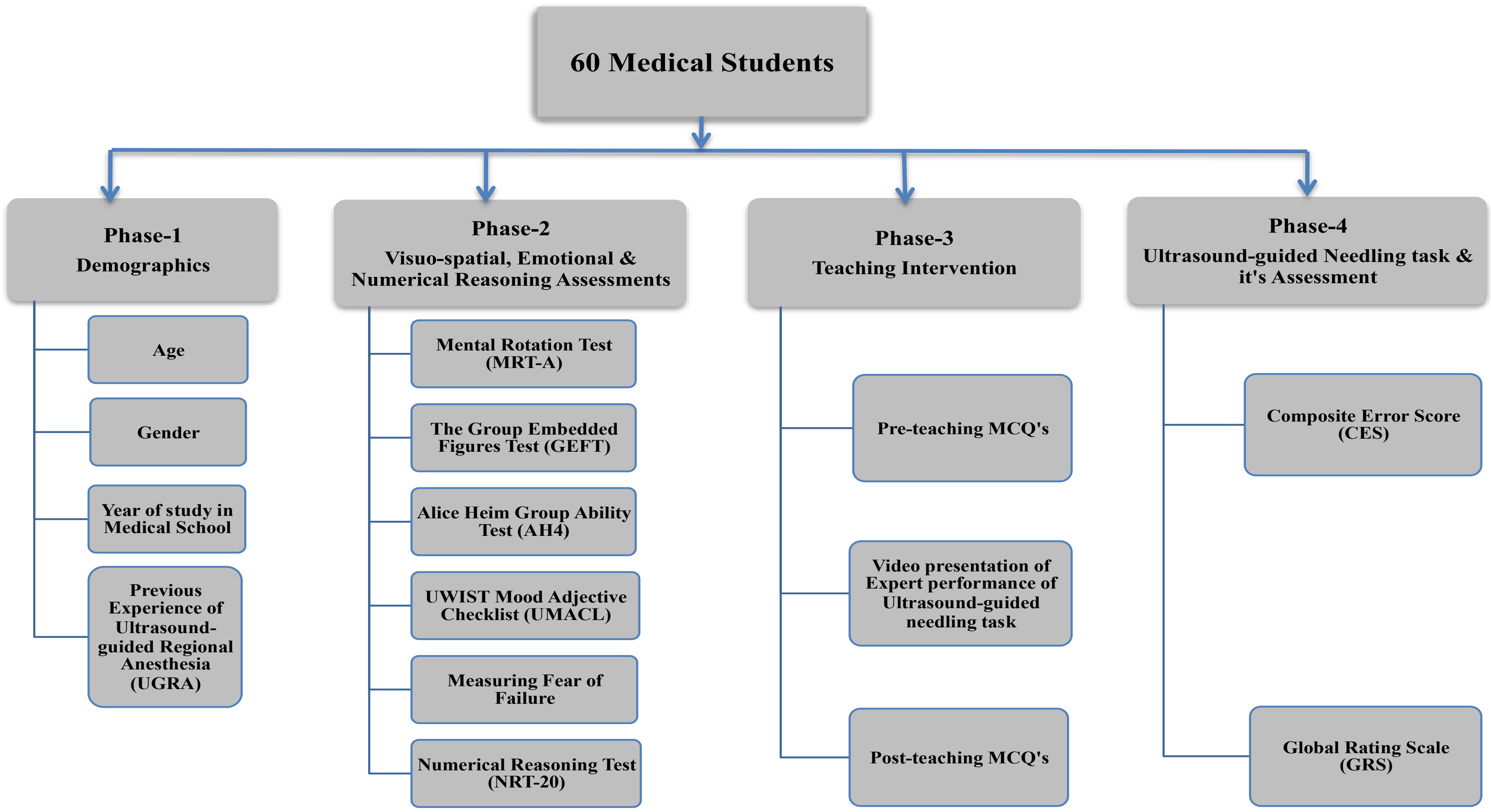

Figure 1. Flowchart showing Study Design

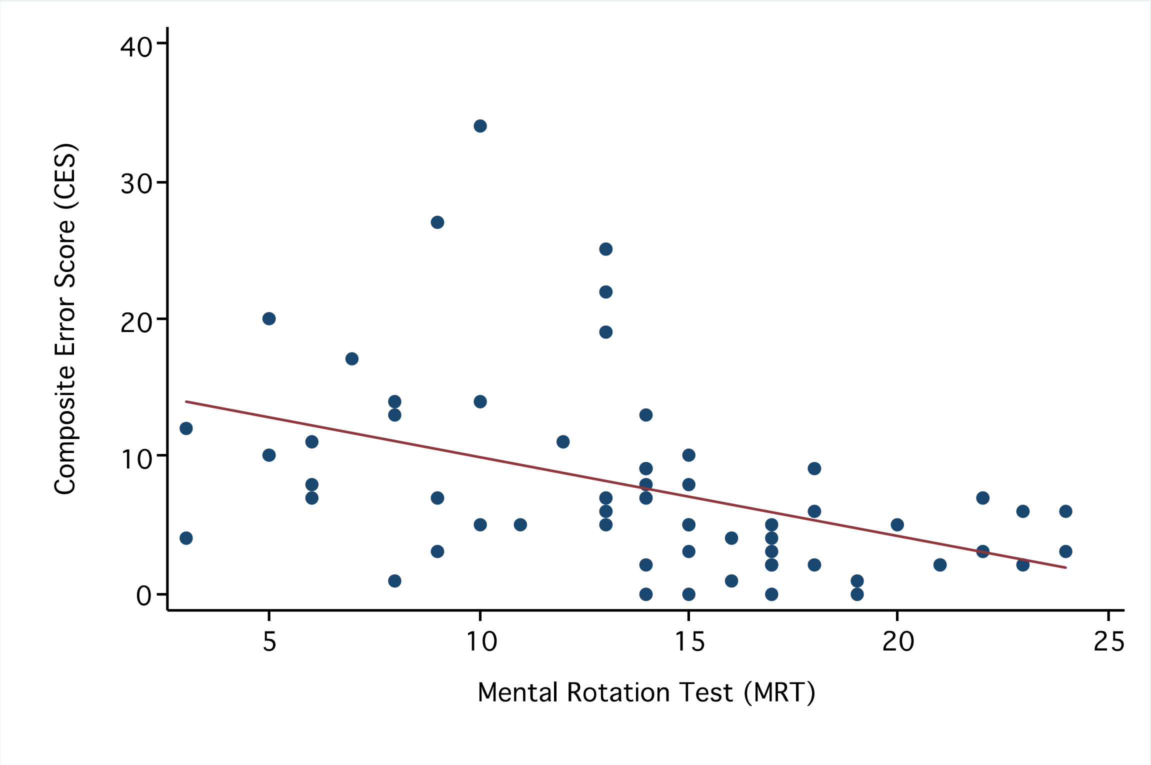

Figure 2. Relationship of CES with MRT.

MRT is negatively correlated with CES, which reveals that increasing error rate is associated with low MRT scores.

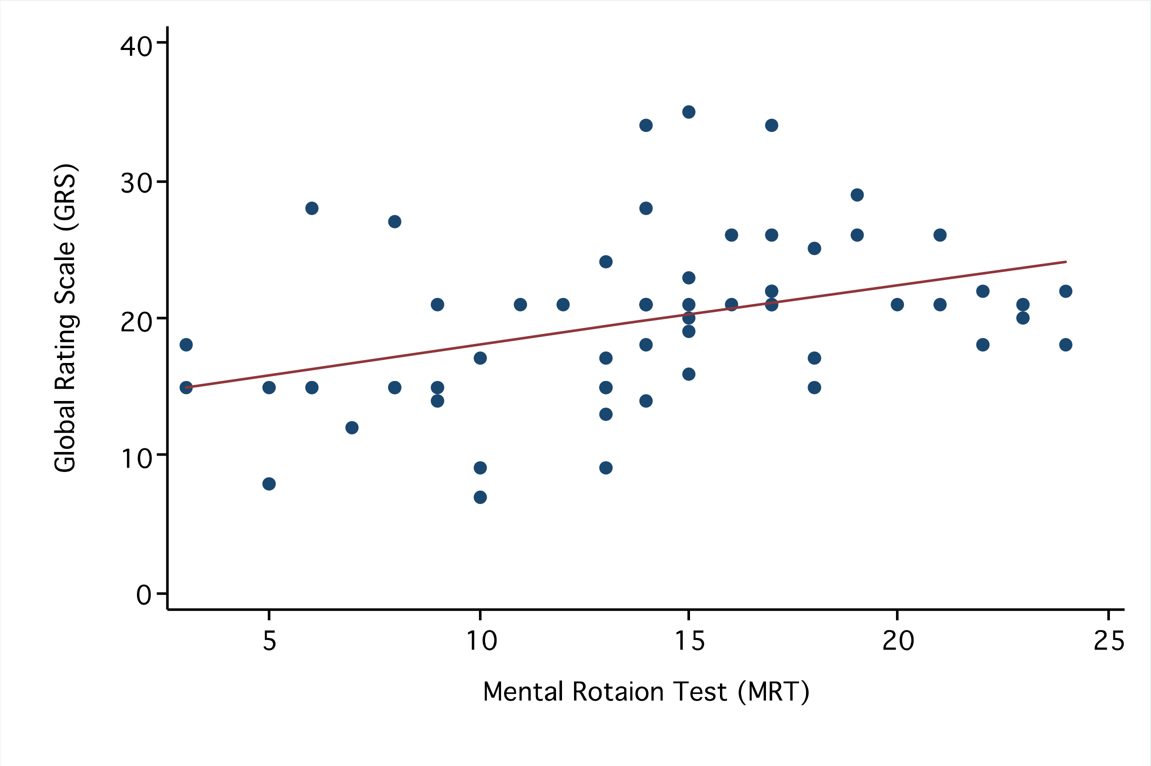

Figure 3. Relationship of GRS with MRT.

MRT is positively correlated with GRS, which shows that enhanced GRS quality scores are associated with high MRT scores.